Art. I.—*On the Relation between Forest Lands and Climate in Victoria.*

By R. L. J. Ellery, F.R.S.

[Read 8th May, 1879.]

The late recurrence of dry seasons in the southern portions of Australia has once more attracted grave public attention to questions concerning the rainfall and conservation of water, and, as is usual during such climatic vicissitudes, numerous opinions and speculations as to periodicity, causation, and so on, find place in the columns of the press. The one, however, which has perhaps obtained more than ordinary interest is that which has reference to the influence of our forests upon rain precipitation and climate.

The full significance of this question only presses on the *public* mind in times of drought and water famine, but it has occupied the attention of scientific men in most countries as a great climatic problem for a long time past. In some instances a partial solution has been reached, appriising the people that such and such deplorable changes of climate were the inevitable and natural result of artificial changes of the earth's surface, to which it had been subjected for centuries. In some countries, therefore, we see what was originally a mild and fertile climate replaced by one of comparative sterility and violent meteorological extremes.

In Australia generally, but more especially in its southern portions, the rainfall is the all-important climatic element; and it is not too much to say that, with an adequate rainfall seasonably distributed throughout the year, the climate of southern Australia would vie in fertility with that of any part of the globe.

There is a law apparent in the general distribution of rainfall upon the earth's surface dependent upon the latitude, which may be roughly stated thus:—While the

average annual rainfall over equatorial regions is about 104 inches, this amount is decreased to

85	inches	in latitude	10°
70	„	„	20°
40	„	„	30°
30	„	„	40°
25	„	„	50°
20	„	„	60°

Our rainfall is approximately in accordance with this law, and although local causes may determine a greater or less amount, the coast-line yearly average may be taken as 33 inches. It would appear, therefore, that our annual average of about 30 inches is what we might naturally expect. Locality, however, has such an important influence in the distribution that in some places not widely separated the annual amount of rainfall will vary as much as 9 inches. The question, therefore, presented to us is this :— Does the presence or absence of forest land govern this unequal distribution ? Will clearing away timber affect the rainfall by diminishing or increasing it in any particular locality, or in any other way ? and (what is also of the greatest importance) do forest lands aid or prevent the natural conservation of the rain which falls to our share ? On these points climatic statistics are meagre, and from only a few countries can we derive any definite experience. This colony has not been settled for a sufficiently long period to afford unmistakable evidence ; and in discussing the question, we must in a large measure necessarily fall back upon the principles and canons of physical science.

Experience, however, supplies us with one or two important facts, first amongst which is that *no marked diminution of average annual rainfall* over any extensive region can be traced solely to denuding the earth's surface of forests, although the local effects of such a proceeding are usually well marked.

If we take countries in temperate latitudes where absence of forest is the normal condition of the surface, we find, with some exceptions, the average annual rainfall agrees fairly with the distribution according to latitude, as given above ; but this average is made up by excessive falls at one portion of the year, or at isolated times, with excessive dryness and scarcity of water as the usual state of things. In some of the timberless districts at the Cape of Good Hope, the beds of the streams, which are dry or nearly so three-fourths of the

year, show how they are torn from time to time by excessive rain precipitation. This is also the case in some parts of temperate South America, Persia, India, Thibet, and Tartary—and, indeed, it is not unknown to us in Australia. In such places drought is the normal state of affairs, though the annual rainfall is probably greater than in wet England. The simple amount of rainfall does not, therefore, appear to be the only factor which determines a country's humidity or dryness; while we gather from the instances referred to that the presence of forests must be taken as one of no small importance.

From carefully conducted experiments it is found that the temperature of trees in forests has a very different march from that of the air, for while the maximum temperature of the air is usually reached about three p.m., that of a forest tree occurs about nine p.m., and while the air is subject to rapid changes, trees are exceedingly slow to alter. The obvious result of this is that the days in a forest are cooler and the nights warmer than in open country. Summer temperature is diminished, and that of winter increased. It is also a well-known fact that forests diminish evaporation from the ground, and act as conservators of moisture.

The greatest extremes of night and day temperature occur in open country, where the unshaded soil readily absorbs the radiant heat of the sun and becomes many degrees hotter than the air. Again rapidly radiating back the heat into space at night (unless it be cloudy), the surface cools down to a temperature far below that of the air, often below freezing point in the middle of summer. Vegetation has a hard struggle for existence; none but the hardiest species survive, and excessive dryness of the untimbered country (where such country prevails to any extent) undoubtedly engenders meteorological conditions unfavourable to rain precipitation. It has also been found that the temperature of the sides and slopes of mountains is modified even in a more marked degree than that of level country by the presence of forests.

So much, then, can be gathered from actual observation and experience in other countries. I now come to our own experience. The greatest annual averages of rain in this colony occur either on or in the vicinity of mountain ranges, and especially on their southern or seaward slopes, and the

least ones on open untimbered level country. For instance, our greatest observed rainfall occurs at Fern-tree Gully, on the south-west slope of the Dandenong Range; next to this come Berwick, and Lower Macedon; then Daylesford, Trentham, Hastings, and Birregurra, all closely-timbered localities or near forest-clad ranges. Our lowest rainfall takes place about Swan Hill and along the western Murray; then comes the Horsham district, and that remarkable area of small rainfall surrounding Cressy, Darlington, Wickliffe, &c.

From this it would appear that, in Victoria, at least, forest lands, if high, are favourable to rain precipitation; while level, open, and sparsely-timbered country is undoubtedly less fortunate in this matter.

We now come to another part of the question—Will denuding the forest lands of timber increase or lessen the rainfall, or will it affect the climate, and how?

Our experience in Victoria does not reach far enough back to answer this question decisively. We have rainfall statistics of only a very few places prior to 1862, and from stations generally distributed over the colony only during the last ten or twelve years. These data are not sufficient to show whether or not any marked change has occurred.

In a few localities, where the clearing of mountain ranges has been carried on extensively, it is gathered from local information that the perennial mountain streams have much diminished; but no actual diminution of rainfall has been shown to have occurred. Yet, nevertheless, it may reasonably be inferred that such has been the case. While, therefore, we fail to obtain any satisfactory reply to this question from precise observation or measurement, physical science will furnish a trustworthy answer to a large part of it.

It has already been remarked that forests greatly reduce the extremes of temperature to which the ground would otherwise be subjected, keeping it warmer by night and cooler by day. *Evaporation from the surface* is also greatly retarded, so that in forest lands the benefits of rain precipitation are thus unusually enhanced, and not only for the timber-clad districts themselves, but also for all areas supplied by streams of which these form the gathering grounds.

Evaporation is always going on from the leaves of trees, and this tends considerably to cool and render less dry the

air over forests. Air nearly saturated with moisture, drifting over the heated surface of the open country and meeting with this cooler stratum, not unfrequently becomes converted into a falling mist or actual rain. In fact, the diminution of temperature over the forest has the same effect upon moisture-laden winds as a range of hills—namely, to encourage precipitation.

It is highly probable that forests have another influence on the atmosphere, which, although not yet thoroughly recognised, and perhaps not generally admitted, may nevertheless prove to be most powerful. I refer to electric influence; and from the results of a few observations and experiments I have made at different times on atmospheric electricity in forests, and some interesting phenomena I have witnessed, I feel certain that what may be called *electric exchange*, or the balancing of the electric tension of the lower strata of the atmosphere over forests, plays an important part in condensation and precipitation. In making an electric contour over large trees in forests, I have always found the equipotential line to come closer to the tops of trees than any other objects; and this may possibly account in part for the well-known rapid condensation by tall trees of the drifting mist in hill forests, by which an immense amount of water, not counted in our rainfall, is annually precipitated.

Some months ago when on Mount Macedon, about 3000 feet above the sea, in company with our Vice-President, Mr. Foord, we watched the gradual condensation of air-borne moisture into mist-clouds. As it was driven up the southern slopes of the mountain, our attention was attracted by some peculiar rifts in the mist-clouds, which occurred as they passed over an isolated dead tree near the summit of the mountain. They appeared as almost vertical dark streamers radiating from the topmost dead limbs of the tree, and waved about much in the same way as one sees the brush discharge from an electric machine, or the secondary discharge of an induction coil. We were both impressed with the idea that the phenomenon was electrical. The part electric tension plays over the surface of forests, presents, I think, a new field for meteorological enquiry.

From these facts, meagre as they are, I think it will be conceded that our forests play a most important part in our climate; that without them, while our rainfall might

not diminish, it would become more fitful, and the country more and more exposed to extremes of temperature, our winds drier, and our soil more arid and sterile. For conserving our allotted rainfall, tempering and moistening the burning equatorial winds, for moderating the sun's powerful rays, and the rapid terrestrial radiation, which produces such low temperatures at night, and for checking rapid evaporation, our forest lands are the chief agents. Denude our timbered ranges, clear away our lower forests, and our climate will soon become like those of some of the similar latitudes in the northern hemisphere already referred to, where no middle state is known between a scorching arid summer and an intensely cold and equally arid winter, tempered only by occasional heavy rains of short duration.

Moderate forest clearing in very humid climates is doubtless beneficial, and many tropical regions have been rendered habitable and healthy by the process; but in a dry climate like that of Southern Australia, the indiscriminate clearing of timbered lands invites an ever-increasing aridity of climate and diminishing fertility of the soil.

Art. II.—*Experiments on the Tensile Strength of a few of the Colonial Timbers.*

By Fred. A. Campbell, C.E.

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These experiments were made at Geelong during a short period of leisure time. As the power I could bring to bear upon the specimens did not exceed a ton, I found it necessary to work upon specimens with a sectional area of one-sixteenth of an inch. The form of specimen first adopted was that shown in figure 1, but as with the stronger woods the specimens gave way by the detrusion of a piece from the centre, as shown by dotted lines, I adopted a form, as in figure 2, five inches longer. The apparatus used was of the